**Digitalearth**
The Digital Earth Network

# Report on Testing and Verifying the Accuracy

Of

*'GeoMode'*
Advanced-Network Software Solution (A-HSS)

For

T-Mobile

Wireless E911 Location Systems

**In accordance with guidelines set out in**

**FCC OET BULLETIN No. 71**

**August 2002**

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***"Turning location information into business intelligence"***

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## I. INTRODUCTION

This document has been prepared to provide the results of field testing of the software to validate that the tested software complies with the accuracy standards set by the Federal Communications Commission (FCC) for 911 Automatic Location Identification (ALI).

The testing and processing methods outlined in this document are intended to produce results meaningful to public safety personnel and persons responsible for wireless system implementation and maintenance. The methods are documented in the FCC E-911 OET Bulletin No.71 and were developed in consultation with interested parties, many with experience in the design and conduct of ALI accuracy tests.

This document includes implementation guidelines and network architecture diagrams and is intended to help encourage E911 deployment by providing guidance to assist wireless equipment manufacturers, wireless carriers, and public safety personnel in designing a GeoMode based ALI system.

The test product is referred to as Advanced Handset Software Solution ("A-HSS") developed by Digital Earth Systems. This location positioning solution is also available as a network-based solution, which is referred to as an Advanced Network Software Solution (A-NSS). Both options are essentially the same product and the principal difference between them is the method of data access. The software tested is a statistical location estimation software product based on the probabilistic modeling of observed propagation data referenced to a wireless propagation data model. The software is used to locate the position of a wireless device within a wireless network. The A-NSS / A-HSS approach uses advanced statistics and decision theory, which differs from previous signal strength methods that attempted to convert signal strength into distance. A-NSS / A-HSS is more accurate, more robust than a geometry / time approach, and can be implemented in any digital signal based network including GSM, GPRS, TDMA, UMTS, WLAN and CDMA.

While there are no established testing standards for location positioning technologies, the A-HSS testing procedures are based on standardized research and development testing procedures, which have been rigorously applied to ensure that the A-HSS ALI system complies with the Commission's Rules.

This document can also be used by public safety groups and organizations working to establish standard test conditions and protocols. It is likely that testing and verification practices will evolve over time as representative models are developed. In addition, it will be possible to establish standardized test procedures that include accuracy measurements for calls made from various caller environments such as indoors, outdoors and walking or moving vehicles.

Currently, there is no good information available regarding locations from which wireless 911 calls are made, and A-HSS testing treated all locations in the selected service area as equally important sources of possible 911 calls.

All ALI technologies will have varying performance in different environments so it is proposed that methods must be developed in the future by which particular technologies can be certified as compliant independent of the operating areas where they may be implemented. It is therefore important to ensure that ALI technologies provide a remedy process for upgrading accuracies in those environments where the Commission's Rules are not met in initial deployment and testing. The public safety goal should be to upgrade the levels of accuracy over time so that the general threshold of 100 meters for 67% of 911 calls approaches 50 meters for 100% of 911 calls.

## II. BACKGROUND

The FCC adopted accuracy and reliability requirements for ALI as part of its rules for wireless carrier enhanced 911 (E911) service in CC Docket No. 94-102, *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems.* Those rules were adopted in 1996 and revised in the Third Report and Order in that docket (released October 6, 1999). The revised rules set the following accuracy and reliability requirements for E911 Phase II operations:

- For network-based solutions: 100 meters for 67 percent of calls, 300 meters for 95 percent of calls;

- For handset-based solutions: 50 meters for 67 percent of calls, 150 meters for 95 percent of calls. The obligation of carriers to deploy such wireless E911 technologies is scheduled to begin next year, in 2001. The standards and the phase-in schedule are incorporated in Section 20.18(g) of the Commission's Rules (47 C.F.R. § 20.18(g)).

## III. GENERAL PRINCIPLES ADOPTED FOR TESTING

**Default Fallback:** The location accuracy requirements that apply to 95 percent of calls. Where Phase II location cannot be provided, Phase I information, *i.e*., the cell site or sector where the call is received, should be reported.

**Uncompleted Calls:** The accuracy data should be calculated only for completed 911 calls consistent with Section 22.921 of the Commission's rules, 47 C.F.R. § 22.921.

**Timing:** While timing information was not recorded as part of the test data, the time to 'fix' a location was well within the 30 seconds defined by the FCC as the acceptable time limit for such testing. The testing demonstrated multiple attempts to determine location within that 30 second where error probability data can be used to select location data with the highest probability of the lowest error in the period. In evaluating compliance, we have adopted and meet the recommendations by the National Emergency Number Association and standards committees regarding time limits for location measurement.

**Motion:** The A-HSS software has demonstrated effective operations in all conditions where 911 calls may be made e.g. from within moving vehicles or stationary / walking at street level. Our 2001 Manhattan testing (see A-HSS Test Results section VII) was completed from a moving vehic le and FCC Phase II accuracy compliance has been verified. We intend to comply with any additional testing guidelines promoted by FCC in included in any modification to OET Bulletin No.71.

**Coverage areas:** Our compliance testing clearly defines the subject geographical areas. Accuracy tests areas are based on a coverage area representative of the local PSAP in Manhattan. Initial testing was completed in 2001 within a 50 square km service area of Manhattan. This area represents a major coverage area within a metropolitan area as suggested by the National Emergency Number Association. Additionally, two sub-areas were chosen for field validation by Voicestream engineering and regulatory staff in the July 2002 field trial. Testing has covered an urban core of the local PSAP response area. Compliance has been verified for two non-overlapping sub-areas separately.

## IV. A-HSS SOFTWARE TESTING

The A-HSS field-testing and verification methods accurately represent real world performance. This testing was achieved through actual empirical testing of a standard Nokia 6210 mobile phone and A-HSS software installed on a laptop server together with a mapping application for visual validation. The two components of A-HSS are:

- The first component is the A-HSS™ software that runs statistical modelling algorithms on the observed wireless signal data between base stations and phones. This software may be installed on a server in the network (SMLC) where is can access the base station controller (BSC) via the 'Lb' interface. A-HSS™ software does not require any network or signalling resource and is fully independent of the network technology. A-HSS is compatible with any standardized network location specific products such as the Ericsson Mobile Positioning System™ (MPS), the Nokia mPosition Solution™ and commercial Location-based Services (LBS) middleware platforms. A-HSS software computes the X,Y location data, in any geographic coordinate system required. A-HSS software is independent of handset type and can locate any legacy handset or messaging communication device.

- The second component is a mathematical signal propagation prediction model. There are three types of models; a network model, or a data model, or a hybrid of both. The network model includes network and base station data provided by the wireless carrier. The data model includes wireless signal propagation data supplied by the carrier or provided by drive testing the network. The hybrid model is a combination of both types of models; it is more efficient than the pure data model. An advantage of the A-HSS data model is that the accuracy of the location positioning system can always be enhanced by additional data collection. The network and data models can also be synchronized to the wireless network maintenance database.

## V. EMPIRICAL TESTING METHODS

An empirical approach was used to verify A-HSS compliance with the FCC accuracy standards. This empirical approach proceeded as follows: An accuracy measurement was made at each point of a sample set of locations randomly selected from within two non-overlapping sub-areas of the Voicestream Wireless service area in Manhattan. This random data set was made up of typical street level locations of ordinary wireless calls and was intended to represent possible 911 call locations.

Location tests were then performed at each of these sample locations to determine the distance between the actual location and the location reported by the ALI system. The actual location was recorded on a digital map application from where map coordinates were recorded. The map coordinates are registered to National Geodetic Survey (NGS) control points with latitude and longitude values. A total of 177 location observations were recorded in the two sub-areas to establish compliance with the FCC accuracy requirements. The testing approach has a statistical confidence of at least 90 percent. See Appendix A for a statistical approach for demonstrating compliance for empirical testing.

**Random Selection of Sample Locations**

In order to ensure a meaningful location sample for determination of confidence, two sub-areas of clearly different environmental characteristics were chosen. One area was selected in Times Square in central Manhattan and noted for its very tall buildings and varying width streets. A second area was chosen on the Upper East Side of Manhattan (Lexington and $78^{th}$) that was representative of the residential portion of Manhattan and surrounding NYC boroughs.

Because both geographic service areas to be tested was bounded by regularly spaced streets, sample locations were selected at several intervals along each street. It was decided that this approach would provide a better representative sample than a selection based on random latitude and longitude values, many of which may be inaccessible. While almost all points selected were outdoors on the street sidewalk, several sample points were selected inside buildings on the ground floor.

**Models for Weighting**

Wireless carriers, the public safety community and the companies involved in location technology have expressed the desire to take into consideration such factors as the likelihood that a wireless 911 call (or any wireless call) will be made from a particular location. However, we believe that the goal should be to ensure a consistent level of acceptable accuracy across the complete coverage service area. One of the many advantages of the statistical modelling approach is that it provides the opportunity to constantly upgrade the accuracy of trouble spots where certain unique environmental features are interfering with the level of accuracy of the location system.

The relationships among radio environment, geographical features, and the inherent variability of a location system are complex There is currently little factual information from which to establish or evaluate weighting factors for 911 caller locations. So the A-HSS statistical modeling approach will always provide a more consistent level of accuracy together with a continuous improvement process.

For the purpose of implementing the FCC testing guidelines, reasonable assumptions have been made in order to begin to develop models. These assumptions are based on consultation with public safety officials with experience in wireless 911 call patterns. As E-911 is implemented, we will have access to real data and weighting factors as to the likelihood, *e.g.*, of a wireless 911 call, from any particular point in the area. This data can then be used by Monte Carlo simulation to upgrade the A-HSS propagation prediction model. As more experience and data is gained, more accurate weighting factors may be developed which will identify areas that need upgrading.

In contrast to geometric approaches, A-HSS uses statistical modelling based on a radio wave propagation prediction model, created from network parameters or empirical data, or a combination of both. This approach treats all signal properties as random variables, which are statistically dependent on the location of the transmitter, the receiver, and the propagation environment. Because of this dependency, an observation of the signal properties is actually a specific inference about the actual location of the observation. The accuracy of this approach therefore not affected by multipath and improved accuracy will always be available by collecting additional propagation data.

**Conventions**

The following testing conventions were used:

- Measurement precision: Latitude and longitude coordinates are expressed in arc-seconds and distance errors from "ground truth" sample locations is computed to the nearest meter. (This convention does not imply that A-HSS is able to determine position with this degree of resolution.) Conventional DGPS location equipment, which typically provides an accuracy of 3 to 5 meters, was. Control survey points from the National Geodetic Survey (NGS) were used to establish the coordinates of sample locations and convert map coordinates to latitude and longitude. NGS data sheets for survey points used are attached in Appendix C.

- Vertical dimension: The A-HSS technology does not measure or report a vertical dimension, *e.g*., for tests made inside buildings on different floors. Two ground level sample locations in buildings were used in the tests. The vertical dimensions are not included in reported statistics. The configuration of most buildings is such that the FCC accuracy standards for Phase II E-911 are not effective for use indoors and it is our view that our WLAN technology, which can deliver 1-meter location accuracy today, will provide usable vertical information inside buildings.

- Statistical confidence: The level of confidence derived from test results were based on order statistics and are stated for 99.9 percent level of confidence in the Times Square area and that the performance is expected to be at least as good in 9 out of 10 test areas with the same relevant characteristics.

- Systematic errors: The largest error observed in the 2002 field trial was 140m and was well within the Phase II limits for handset based location technology. No special reporting has been prepared to identify unusually large errors.

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- Handset environment: The testing reflected the expected use of the handset including the effects of holding the handset next to the head, in a vehicle, behind large vehicles. The 2002 testing was completed on foot in two sub-areas of the A-HSS Manhattan Model. One area was selected near the Times Square and another was selected in the Upper East Side area. Each area was approximately 1 square km in area and included 147 and 30 data points respectively. Our 2001 testing was completed in Manhattan between 14$^{th}$ Street to 150$^{th}$ Street and the service area consisted of approximately 50 square kms. This testing was from a moving vehicle and so reflected the effects of calling from within vehicles.

- Portable and mobile phones: The testing was completed on a standard Nokia 6210, which reflects a popular handset type. The phone was purchased at a Voicestream store and a Voicestream Pre-Paid SIM card was purchased.

- Air interface: The testing was completed on the Voicestream GSM service in Manhattan.

## VI. PREDICTIVE TESTING METHODS

Standard predictive methods are essential for the evaluation of all ALI systems, and Appendix A in this document includes a description of the predictive model used to evaluate A-HSS. While A-HSS technology may vary in performance in varying environments, the predictive model used in the Manhattan Field Trial data was not based on any classification of different types of environments. The location errors throughout the field-testing were well within the FCC standards for all environments such as urban settings such as "urban canyons" (locations between high-rise buildings); suburban settings such as the Upper East Side that includes residential houses and streets. Sufficient testing has not been done in rural settings distinguished by terrain and vegetation coverage however, the nature of the A-HSS mathematical process means that the results in rural settings will be influenced by service quality and by the geometry (and density) of base station locations rather than terrain variations.

### General Form of Prediction Models

Because of the way the FCC standards are stated, A-HSS performance field-testing involved cumulative distribution functions representing expected location errors. All test results have been processed to provide a prediction of the probabilities *P1* and *P2* corresponding respectively to location errors within the 67% and 95% FCC accuracy standards. While the A-HSS software can be either network or handset based, the implementation demonstrated in the field trial was handset-based, and the maximum *P1* value was 32 meters (FCC limit is 50m), and the maximum *P2* value was 89 meters (FCC limit is 150 meters). For network-based solutions, the predicted probabilities of location error limits are 100 meters and 300 meters respectively.

The NYC Manhattan service area includes very demanding environments, and the A-HSS ALI technology demonstrated accuracies where the probabilities exceeded the standard minimum FCC values.

The models used for determining the predicted probabilities of location errors are clearly defined in a manner appropriate for publication in technical journals and described in Appendix A.

### Application of Prediction Models

All test results demonstrated that the probabilities *P1* and *P2* easily meet the target values of 67% and 95% in all Manhattan urban environments tested. Weighted averages based on the possibility or likelihood of E911 calls from various locations in the particular service area tested were not computed.

The total Manhattan service area (approximately 50 square km) was divided into two smaller sub-areas (approximately 1 square km. Each) with probabilities *P1* and *P2* in each predicted by model parameters specifically applicable to the respective sub-area. Full compliance with FCC accuracy was demonstrated for all areas.

The service areas tested were urban high-rise and urban medium-rise residential areas. This field trial did not include any rural areas or areas with low density cell coverage.

## VII. A-HSS TESTING RESULTS

The results of field trial testing in three areas of New York City during 2001 and 2002 are summarized below. Additionally, a cumulative probability graph is provided showing the probability for all errors. The field trials dated July 2002 were validated in the field by engineering and regulatory staff from Voicestream Wireless.

### A-HSS Field Trial Accuracy Summary

| A-HSS Test Area | Test Date | Area Sq. Kms. | # Of Calls | Error 67% | Error 95% | Confidence Level |
|---|---|---|---|---|---|---|
| Upper East Side | 07/23/02 | 1 | 30 | 32m | 60m | 78.50% |
| Times Square | 07/23/02 | 1 | 147 | 30m | 89m | 99.90% |
| | | | | | | |

## GLOSSARY OF TERMS

Advanced Handset Software Solution (A-HSS) – refers to the handset implementation of GeoMode software product for locating wireless mobile handsets and devices.

Advanced Network Software Solution (A-NSS) – refers to the network implementation of GeoMode software product for locating wireless mobile handsets and devices.

Automatic Location Identification (ALI) - Delivery of the location of a wireless handset to a PSAP without the need for inquiry by the dispatcher

Differential GPS (DGPS) – A method for correcting inaccuracies in GPS location calculations by use of signals from a terrestrial reference station.

Enhanced 911 (E911) – An emergency telephone system using the digits 9-1-1 that provides additional information to the emergency dispatcher, such as Automatic Number Identification and Automatic Location Identification.

Global Positioning System (GPS) – A network of 24 U.S. government satellites, supported by ground control systems, transmitting radio signals that can be decoded to compute precise locations.

Handset-based Location Technology - A method of providing the location of wireless 911 callers that requires the use of special location-determining hardware and/or software in a portable or mobile phone. Handset-based location technology may also employ additional location-determining hardware and/or software in the wireless network and/or another fixed infrastructure.

Network-based Location technology - A method of providing the location of wireless 911 callers that employs hardware and/or software in the wireless network and/or another fixed infrastructure, and does not require the use of special location determining hardware and/or software in the caller's portable or mobile phone.

Public Safety Answering Point (PSAP) – A 911 answering station designated to receive 911 calls from a specific geographic area.

Phase I E911 – The first step in implementing wireless E911. Under Phase I, as of April 1, 1998, licensees subject to the E911 rules must provide the telephone number of the originator of the 911 call and the location of the cell site or base station receiving the call from any mobile handset accessing their systems to the designated PSAP. This requirement applies only if certain conditions are met: that the PSAP has requested the service and is capable of receiving and utilizing the data, and that a mechanism for recovery of the PSAP's costs is in place.

Phase II E911 – The second step in implementing wireless E911. Under Phase II, as of October 1, 2001, licensees subject to the E911 rules must provide to the PSAP the location of all 911 calls by longitude and latitude in conformance with specified accuracy requirements, subject to the same conditions that apply to Phase I. Wireless carriers are required to report their plans for 10 implementing Phase II, including the technology they plan to use to provide caller location, by October 1, 2000.

**APPENDICES**

A. E-911 location positioning accuracy compliance

B. A-HSS Field Trial Results

C. NGS Survey Data Sheets

D. Field Trial Agenda / Participants

F. A-NSS / A-HSS Implementation / Guidelines

# APPENDIX A

## E-911 Location Positioning Accuracy Compliance

**Digitalearth**

22 September 2002

Voicestream Wireless
12920 SE 38th Street
Bellevue, WA 98006

Attn: E911 Regulatory Manager

*RE: GeoMode E-911 Compliance for Empirical Testing*

Below are the summary results of the GeoMode location positioning software, which was tested for Voicestream Wireless on 23 July 2002 in Manhattan, New York. The purpose of the testing was to evaluate compliance with the FCC E911 Mandate Phase II accuracy requirements specified in CC Docket No. 94-102, released on October 6, 1999.

| GeoMode Test Area | Test Date | Area Sq. Kms. | # Of Calls | Error 67% | Error 95% | Confidence Level |
|---|---|---|---|---|---|---|
| Upper East Side | 07/23/02 | 1 | 30 | 32m | 60m | 78.50% |
| Times Square | 07/23/02 | 1 | 147 | 30m | 89m | 99.90% |
| | | | | | | |

According to the FCC Mandate, a specific set of accuracy measurements is said to show compliance if the confidence intervals contain the location error thresholds established by the FCC. These are 100 meters for 67% and 300 meters for 95% for network-based solutions, or 50 meters and 150 meters, respectively for handset-based solutions.

The testing procedures were generally in accordance with the guidelines and suggestions for evaluating compliance set out in FCC OET BULLETIN No. 71. The reliability of the results was determined from order statistics using the method described in OET Bulletin No. 71 Appendix A.

The GeoMode software tested in this trial complies with accuracy requirements specified in the FCC Mandate for E-911 (CC Docket No. 94-102) for both the network based and handset based solutions.

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**Note on order statistics and the suggested methodology for determining confidence levels**

The suggested formula is acceptable for large values of n, but is not suitable when the value of n is small. There is a nice theoretical reasons for this, but the following example demonstrates the problem of order statistics (the theory behind the formula) in general and problems of this particular application of order statistics in case of small n. (As a mathematical theory order statistics is of course very valid, but some care should be taken to blindly applying it.

Example: let us have 10 randomly selected test locations and let us assume that our locationing method makes 99m errors in every test (i.e. 10 times). The order statistics specified by the FCC indicate (by applying the formula) that there is 40% chance that in the future at least 67% of errors are less than 100m and at least 95% of errors are less than 300m.

Let us now have the other locationing method that does not make any errors (i.e. error is 0m) in these 10 test points. The FCC-formula gives exactly the same result as in the previous case: confidence level of meeting requirements is 40%.

Even if have 40 test points and our estimation method gives zero error in all of them, the confidence level is only 87%.

Dr. Henry Tirri
Helsinki
22 September 2002

# APPENDIX B

## Field Trial Results from A-HSS E-911 Compliance for Empirical Testing

- **Times Square, NY**
- **Upper East Side, NY**

**A-HSS Field Trial Results:** Times Square, New York City

**Date:** 23-Jul-02

**Lat/Long1 = Actual Positions and Lat/Long2 = A-HSS Positions**

| Point | Lat1 | Long1 | Lat2 | Long2 | All Errors | Best 95% | Best 67% |
|---|---|---|---|---|---|---|---|
| 1 | 40 45' 28" N | 73 59' 1" W | 40 45' 28" N | 73 59' 1" W | 0 | 0 | 0 |
| 2 | 40 45' 27" N | 73 58' 57" W | 40 45' 27" N | 73 58' 58" W | 28 | 28 | 28 |
| 3 | 40 45' 25" N | 73 58' 57" W | 40 45' 25" N | 73 58' 58" W | 11 | 11 | 11 |
| 4 | 40 45' 25" N | 73 59' 0" W | 40 45' 25" N | 73 59' 1" W | 28 | 28 | 28 |
| 5 | 40 45' 27" N | 73 59' 4" W | 40 45' 27" N | 73 59' 4" W | 15 | 15 | 15 |
| 6 | 40 45' 27" N | 73 59' 7" W | 40 45' 27" N | 73 59' 7" W | 9 | 9 | 9 |
| 7 | 40 45' 26" N | 73 59' 8" W | 40 45' 24" N | 73 59' 7" W | 60 | 60 | |
| 8 | 40 45' 27" N | 73 59' 12" W | 40 45' 29" N | 73 59' 15" W | 82 | 82 | |
| 9 | 40 45' 29" N | 73 59' 15" W | 40 45' 29" N | 73 59' 15" W | 1 | 1 | 1 |
| 10 | 40 45' 30" N | 73 59' 17" W | 40 45' 30" N | 73 59' 17" W | 12 | 12 | 12 |
| 11 | 40 45' 31" N | 73 59' 14" W | 40 45' 31" N | 73 59' 14" W | 8 | 8 | 8 |
| 12 | 40 45' 29" N | 73 59' 11" W | 40 45' 26" N | 73 59' 8" W | 135 | | |
| 13 | 40 45' 30" N | 73 59' 9" W | 40 45' 30" N | 73 59' 9" W | 1 | 1 | 1 |
| 14 | 40 45' 31" N | 73 59' 8" W | 40 45' 30" N | 73 59' 7" W | 36 | 36 | |
| 15 | 40 45' 30" N | 73 59' 7" W | 40 45' 30" N | 73 59' 7" W | 2 | 2 | 2 |
| 16 | 40 45' 30" N | 73 59' 7" W | 40 45' 30" N | 73 59' 7" W | 13 | 13 | 13 |
| 17 | 40 45' 31" N | 73 59' 9" W | 40 45' 31" N | 73 59' 9" W | 5 | 5 | 5 |
| 18 | 40 45' 32" N | 73 59' 12" W | 40 45' 32" N | 73 59' 11" W | 30 | 30 | 30 |
| 19 | 40 45' 32" N | 73 59' 14" W | 40 45' 32" N | 73 59' 14" W | 4 | 4 | 4 |
| 20 | 40 45' 31" N | 73 59' 14" W | 40 45' 31" N | 73 59' 14" W | 5 | 5 | 5 |
| 21 | 40 45' 31" N | 73 59' 17" W | 40 45' 30" N | 73 59' 17" W | 12 | 12 | 12 |
| 22 | 40 45' 30" N | 73 59' 18" W | 40 45' 30" N | 73 59' 17" W | 26 | 26 | 26 |
| 23 | 40 45' 28" N | 73 59' 13" W | 40 45' 28" N | 73 59' 13" W | 1 | 1 | 1 |
| 24 | 40 45' 28" N | 73 59' 12" W | 40 45' 28" N | 73 59' 13" W | 34 | 34 | |
| 25 | 40 45' 26" N | 73 59' 9" W | 40 45' 25" N | 73 59' 7" W | 53 | 53 | |
| 26 | 40 45' 26" N | 73 59' 8" W | 40 45' 26" N | 73 59' 8" W | 11 | 11 | 11 |
| 27 | 40 45' 25" N | 73 59' 6" W | 40 45' 25" N | 73 59' 6" W | 1 | 1 | 1 |
| 28 | 40 45' 23" N | 73 59' 1" W | 40 45' 24" N | 73 59' 2" W | 22 | 22 | 22 |
| 29 | 40 45' 24" N | 73 58' 58" W | 40 45' 24" N | 73 58' 58" W | 17 | 17 | 17 |
| 30 | 40 45' 26" N | 73 59' 2" W | 40 45' 25" N | 73 59' 1" W | 21 | 21 | 21 |
| 31 | 40 45' 27" N | 73 59' 4" W | 40 45' 28" N | 73 59' 5" W | 28 | 28 | 28 |
| 33 | 40 45' 29" N | 73 59' 6" W | 40 45' 29" N | 73 59' 6" W | 18 | 18 | 18 |
| 34 | 40 45' 30" N | 73 59' 5" W | 40 45' 31" N | 73 59' 5" W | 8 | 8 | 8 |
| 35 | 40 45' 31" N | 73 59' 6" W | 40 45' 31" N | 73 59' 5" W | 17 | 17 | 17 |
| 36 | 40 45' 26" N | 73 58' 57" W | 40 45' 26" N | 73 58' 57" W | 0 | 0 | 0 |
| 37 | 40 45' 26" N | 73 58' 57" W | 40 45' 25" N | 73 58' 58" W | 47 | 47 | |
| 38 | 40 45' 27" N | 73 58' 58" W | 40 45' 28" N | 73 59' 0" W | 43 | 43 | |
| 39 | 40 45' 28" N | 73 59' 1" W | 40 45' 28" N | 73 59' 0" W | 7 | 7 | 7 |
| 40 | 40 45' 29" N | 73 59' 3" W | 40 45' 29" N | 73 59' 3" W | 14 | 14 | 14 |
| 41 | 40 45' 30" N | 73 59' 5" W | 40 45' 30" N | 73 59' 5" W | 8 | 8 | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42 | 40 45' 29" N | 73 59' 6" W | 40 45' 29" N | 73 59' 6" W | 14 | 14 | 14 |
| 43 | 40 45' 28" N | 73 59' 6" W | 40 45' 28" N | 73 59' 6" W | 0 | 0 | 0 |
| 44 | 40 45' 27" N | 73 59' 4" W | 40 45' 29" N | 73 59' 9" W | **140** | | |
| 45 | 40 45' 26" N | 73 59' 2" W | 40 45' 26" N | 73 59' 1" W | 16 | 16 | 16 |
| 46 | 40 45' 26" N | 73 58' 59" W | 40 45' 24" N | 73 59' 0" W | 62 | 62 | |
| 47 | 40 45' 25" N | 73 58' 58" W | 40 45' 24" N | 73 58' 58" W | 37 | 37 | |
| 48 | 40 45' 24" N | 73 58' 58" W | 40 45' 23" N | 73 58' 59" W | 26 | 26 | 26 |
| 49 | 40 45' 25" N | 73 59' 0" W | 40 45' 24" N | 73 58' 58" W | 50 | 50 | |
| 50 | 40 45' 26" N | 73 59' 2" W | 40 45' 26" N | 73 59' 1" W | 22 | 22 | 22 |
| 51 | 40 45' 27" N | 73 59' 4" W | 40 45' 27" N | 73 59' 5" W | 23 | 23 | 23 |
| 52 | 40 45' 27" N | 73 59' 7" W | 40 45' 27" N | 73 59' 7" W | 30 | 30 | 30 |
| 53 | 40 45' 27" N | 73 59' 7" W | 40 45' 27" N | 73 59' 7" W | 19 | 19 | 19 |
| 54 | 40 45' 26" N | 73 59' 8" W | 40 45' 26" N | 73 59' 8" W | 14 | 14 | 14 |
| 55 | 40 45' 25" N | 73 59' 6" W | 40 45' 26" N | 73 59' 7" W | 42 | 42 | |
| 56 | 40 45' 24" N | 73 59' 3" W | 40 45' 24" N | 73 59' 3" W | 4 | 4 | 4 |
| 57 | 40 45' 23" N | 73 59' 1" W | 40 45' 23" N | 73 59' 1" W | 7 | 7 | 7 |
| 58 | 40 45' 23" N | 73 58' 59" W | 40 45' 22" N | 73 59' 0" W | 19 | 19 | 19 |
| 59 | 40 45' 23" N | 73 58' 59" W | 40 45' 24" N | 73 58' 59" W | 8 | 8 | 8 |
| 60 | 40 45' 30" N | 73 59' 7" W | 40 45' 30" N | 73 59' 7" W | 7 | 7 | 7 |
| 61 | 40 45' 30" N | 73 59' 7" W | 40 45' 29" N | 73 59' 7" W | 37 | 37 | |
| 62 | 40 45' 31" N | 73 59' 9" W | 40 45' 29" N | 73 59' 13" W | 115 | | |
| 63 | 40 45' 32" N | 73 59' 11" W | 40 45' 32" N | 73 59' 12" W | 10 | 10 | 10 |
| 64 | 40 45' 33" N | 73 59' 13" W | 40 45' 32" N | 73 59' 12" W | 13 | 13 | 13 |
| 65 | 40 45' 33" N | 73 59' 15" W | 40 45' 33" N | 73 59' 15" W | 25 | 25 | 25 |
| 66 | 40 45' 33" N | 73 59' 15" W | 40 45' 31" N | 73 59' 16" W | 48 | 48 | |
| 67 | 40 45' 32" N | 73 59' 16" W | 40 45' 30" N | 73 59' 17" W | 47 | 47 | |
| 68 | 40 45' 31" N | 73 59' 14" W | 40 45' 30" N | 73 59' 13" W | 34 | 34 | |
| 70 | 40 45' 29" N | 73 59' 10" W | 40 45' 29" N | 73 59' 11" W | 32 | 32 | |
| 71 | 40 45' 29" N | 73 59' 8" W | 40 45' 29" N | 73 59' 8" W | 5 | 5 | 5 |
| 72 | 40 45' 28" N | 73 59' 8" W | 40 45' 29" N | 73 59' 8" W | 29 | 29 | 29 |
| 73 | 40 45' 29" N | 73 59' 10" W | 40 45' 30" N | 73 59' 12" W | 63 | 63 | |
| 74 | 40 45' 30" N | 73 59' 12" W | 40 45' 30" N | 73 59' 12" W | 0 | 0 | 0 |
| 75 | 40 45' 30" N | 73 59' 14" W | 40 45' 31" N | 73 59' 14" W | 15 | 15 | 15 |
| 76 | 40 45' 31" N | 73 59' 16" W | 40 45' 31" N | 73 59' 16" W | 11 | 11 | 11 |
| 77 | 40 45' 30" N | 73 59' 17" W | 40 45' 30" N | 73 59' 17" W | 1 | 1 | 1 |
| 78 | 40 45' 30" N | 73 59' 17" W | 40 45' 30" N | 73 59' 17" W | 0 | 0 | 0 |
| 79 | 40 45' 29" N | 73 59' 15" W | 40 45' 28" N | 73 59' 13" W | 55 | 55 | |
| 80 | 40 45' 28" N | 73 59' 13" W | 40 45' 27" N | 73 59' 11" W | 70 | 70 | |
| 81 | 40 45' 27" N | 73 59' 11" W | 40 45' 27" N | 73 59' 11" W | 5 | 5 | 5 |
| 82 | 40 45' 26" N | 73 59' 9" W | 40 45' 27" N | 73 59' 9" W | 9 | 9 | 9 |
| 83 | 40 45' 27" N | 73 59' 8" W | 40 45' 27" N | 73 59' 8" W | 20 | 20 | 20 |
| 84 | 40 45' 25" N | 73 59' 10" W | 40 45' 24" N | 73 59' 10" W | 30 | 30 | 30 |
| 85 | 40 45' 26" N | 73 59' 9" W | 40 45' 25" N | 73 59' 9" W | 24 | 24 | 24 |
| 86 | 40 45' 27" N | 73 59' 12" W | 40 45' 28" N | 73 59' 15" W | 89 | **89** | |
| 88 | 40 45' 29" N | 73 59' 18" W | 40 45' 29" N | 73 59' 17" W | 33 | 33 | |
| 89 | 40 45' 28" N | 73 59' 18" W | 40 45' 28" N | 73 59' 18" W | 1 | 1 | 1 |
| 90 | 40 45' 27" N | 73 59' 19" W | 40 45' 30" N | 73 59' 18" W | 76 | 76 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 91 | 40 45' 27" N | 73 59' 17" W | 40 45' 26" N | 73 59' 17" W | 13 | 13 | 13 |
| 92 | 40 45' 26" N | 73 59' 15" W | 40 45' 24" N | 73 59' 13" W | 63 | 63 | |
| 93 | 40 45' 25" N | 73 59' 13" W | 40 45' 24" N | 73 59' 13" W | 21 | 21 | 21 |
| 94 | 40 45' 24" N | 73 59' 10" W | 40 45' 24" N | 73 59' 10" W | 25 | 25 | 25 |
| 95 | 40 45' 23" N | 73 59' 11" W | 40 45' 24" N | 73 59' 10" W | 29 | 29 | 29 |
| 97 | 40 45' 25" N | 73 59' 15" W | 40 45' 25" N | 73 59' 15" W | 0 | 0 | 0 |
| 98 | 40 45' 26" N | 73 59' 17" W | 40 45' 27" N | 73 59' 18" W | 30 | 30 | **30** |
| 99 | 40 45' 27" N | 73 59' 19" W | 40 45' 27" N | 73 59' 19" W | 3 | 3 | 3 |
| 100 | 40 45' 26" N | 73 59' 20" W | 40 45' 26" N | 73 59' 20" W | 8 | 8 | 8 |
| 101 | 40 45' 25" N | 73 59' 20" W | 40 45' 26" N | 73 59' 20" W | 34 | 34 | |
| 102 | 40 45' 24" N | 73 59' 19" W | 40 45' 24" N | 73 59' 18" W | 1 | 1 | 1 |
| 103 | 40 45' 24" N | 73 59' 16" W | 40 45' 24" N | 73 59' 17" W | 16 | 16 | 16 |
| 104 | 40 45' 23" N | 73 59' 14" W | 40 45' 21" N | 73 59' 10" W | 107 | | |
| 105 | 40 45' 22" N | 73 59' 12" W | 40 45' 24" N | 73 59' 10" W | 77 | 77 | |
| 106 | 40 45' 23" N | 73 59' 11" W | 40 45' 23" N | 73 59' 10" W | 42 | 42 | |
| 107 | 40 45' 21" N | 73 59' 0" W | 40 45' 21" N | 73 59' 0" W | 1 | 1 | 1 |
| 108 | 40 45' 22" N | 73 59' 0" W | 40 45' 21" N | 73 59' 0" W | 39 | 39 | |
| 109 | 40 45' 23" N | 73 59' 1" W | 40 45' 23" N | 73 59' 1" W | 16 | 16 | 16 |
| 110 | 40 45' 24" N | 73 59' 4" W | 40 45' 24" N | 73 59' 3" W | 11 | 11 | 11 |
| 111 | 40 45' 24" N | 73 59' 6" W | 40 45' 25" N | 73 59' 6" W | 26 | 26 | 26 |
| 112 | 40 45' 25" N | 73 59' 8" W | 40 45' 27" N | 73 59' 9" W | 50 | 50 | |
| 113 | 40 45' 24" N | 73 59' 8" W | 40 45' 24" N | 73 59' 9" W | 20 | 20 | 20 |
| 114 | 40 45' 23" N | 73 59' 8" W | 40 45' 23" N | 73 59' 9" W | 11 | 11 | 11 |
| 115 | 40 45' 23" N | 73 59' 7" W | 40 45' 22" N | 73 59' 5" W | 55 | 55 | |
| 116 | 40 45' 22" N | 73 59' 5" W | 40 45' 21" N | 73 59' 5" W | 16 | 16 | 16 |
| 117 | 40 45' 21" N | 73 59' 2" W | 40 45' 22" N | 73 59' 5" W | 59 | 59 | |
| 118 | 40 45' 20" N | 73 59' 1" W | 40 45' 20" N | 73 59' 1" W | 23 | 23 | 23 |
| 119 | 40 45' 20" N | 73 59' 1" W | 40 45' 21" N | 73 59' 0" W | 35 | 35 | |
| 120 | 40 45' 20" N | 73 59' 3" W | 40 45' 21" N | 73 59' 2" W | 23 | 23 | 23 |
| 121 | 40 45' 21" N | 73 59' 5" W | 40 45' 22" N | 73 59' 7" W | 62 | 62 | |
| 122 | 40 45' 22" N | 73 59' 7" W | 40 45' 22" N | 73 59' 5" W | 44 | 44 | |
| 123 | 40 45' 23" N | 73 59' 9" W | 40 45' 22" N | 73 59' 9" W | 29 | 29 | 29 |
| 124 | 40 45' 22" N | 73 59' 9" W | 40 45' 23" N | 73 59' 9" W | 51 | 51 | |
| 125 | 40 45' 21" N | 73 59' 9" W | 40 45' 21" N | 73 59' 9" W | 15 | 15 | 15 |
| 126 | 40 45' 20" N | 73 59' 7" W | 40 45' 20" N | 73 59' 7" W | 16 | 16 | 16 |
| 127 | 40 45' 20" N | 73 59' 6" W | 40 45' 20" N | 73 59' 8" W | 55 | 55 | |
| 128 | 40 45' 19" N | 73 59' 4" W | 40 45' 19" N | 73 59' 4" W | 4 | 4 | 4 |
| 129 | 40 45' 18" N | 73 59' 2" W | 40 45' 21" N | 73 59' 2" W | 82 | 82 | |
| 130 | 40 45' 19" N | 73 59' 2" W | 40 45' 21" N | 73 59' 1" W | 66 | 66 | |
| 131 | 40 45' 31" N | 73 59' 9" W | 40 45' 31" N | 73 59' 8" W | 34 | 34 | |
| 132 | 40 45' 32" N | 73 59' 11" W | 40 45' 31" N | 73 59' 8" W | 95 | | |
| 133 | 40 45' 30" N | 73 59' 17" W | 40 45' 30" N | 73 59' 17" W | 2 | 2 | 2 |
| 134 | 40 45' 28" N | 73 59' 18" W | 40 45' 28" N | 73 59' 19" W | 5 | 5 | 5 |
| 135 | 40 45' 27" N | 73 59' 18" W | 40 45' 27" N | 73 59' 18" W | 0 | 0 | 0 |
| 136 | 40 45' 27" N | 73 59' 17" W | 40 45' 26" N | 73 59' 16" W | 18 | 18 | 18 |
| 138 | 40 45' 22" N | 73 59' 6" W | 40 45' 24" N | 73 59' 11" W | 134 | | |
| 139 | 40 45' 21" N | 73 59' 5" W | 40 45' 21" N | 73 59' 5" W | 7 | 7 | 7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 140 | 40 45' 20" N | 73 59' 3" W | 40 45' 21" N | 73 59' 3" W | 4 | 4 | 4 |
| 141 | 40 45' 19" N | 73 59' 4" W | 40 45' 19" N | 73 59' 4" W | 8 | 8 | 8 |
| 142 | 40 45' 20" N | 73 59' 6" W | 40 45' 20" N | 73 59' 7" W | 32 | 32 | |
| 143 | 40 45' 21" N | 73 59' 9" W | 40 45' 21" N | 73 59' 9" W | 2 | 2 | 2 |
| 144 | 40 45' 24" N | 73 59' 5" W | 40 45' 25" N | 73 59' 6" W | 28 | 28 | 28 |
| 145 | 40 45' 24" N | 73 59' 4" W | 40 45' 24" N | 73 59' 4" W | 14 | 14 | 14 |
| 146 | 40 45' 23" N | 73 59' 1" W | 40 45' 23" N | 73 59' 1" W | 1 | 1 | 1 |
| 147 | 40 45' 23" N | 73 59' 8" W | 40 45' 23" N | 73 59' 9" W | 21 | 21 | 21 |

**A-HSS Field Trial Results:** Upper East Side, New York City

**Date:** 23-Jul-02

**Lat/Long1 = Actual Positions and Lat/Long2 = A-HSS Positions**

| Point | Lat1 | Long1 | Lat2 | Long2 | All Errors | Best 95% | Best 67% |
|---|---|---|---|---|---|---|---|
| 1 | 40 46' 17" N | 73 57' 46" W | 40 46' 17" N | 73 57' 45" W | 32 | 32 | **32** |
| 2 | 40 46' 18" N | 73 57' 47" W | 40 46' 18" N | 73 57' 47" W | 15 | 15 | 15 |
| 3 | 40 46' 18" N | 73 57' 48" W | 40 46' 17" N | 73 57' 47" W | 27 | 27 | 27 |
| 4 | 40 46' 18" N | 73 57' 48" W | 40 46' 18" N | 73 57' 49" W | 14 | 14 | 14 |
| 5 | 40 46' 18" N | 73 57' 51" W | 40 46' 19" N | 73 57' 53" W | 43 | 43 | |
| 6 | 40 46' 19" N | 73 57' 53" W | 40 46' 19" N | 73 57' 53" W | 1 | 1 | 1 |
| 7 | 40 46' 20" N | 73 57' 52" W | 40 46' 20" N | 73 57' 52" W | 18 | 18 | 18 |
| 8 | 40 46' 22" N | 73 57' 51" W | 40 46' 19" N | 73 57' 53" W | 75 | | |
| 9 | 40 46' 22" N | 73 57' 51" W | 40 46' 21" N | 73 57' 48" W | **89** | | |
| 10 | 40 46' 21" N | 73 57' 49" W | 40 46' 21" N | 73 57' 47" W | 60 | **60** | |
| 11 | 40 46' 21" N | 73 57' 49" W | 40 46' 20" N | 73 57' 47" W | 53 | 53 | |
| 12 | 40 46' 20" N | 73 57' 46" W | 40 46' 20" N | 73 57' 46" W | 19 | 19 | 19 |
| 13 | 40 46' 20" N | 73 57' 45" W | 40 46' 20" N | 73 57' 46" W | 23 | 23 | 23 |
| 14 | 40 46' 19" N | 73 57' 45" W | 40 46' 19" N | 73 57' 46" W | 17 | 17 | 17 |
| 15 | 40 46' 17" N | 73 57' 45" W | 40 46' 17" N | 73 57' 48" W | 56 | 56 | |
| 16 | 40 46' 17" N | 73 57' 45" W | 40 46' 17" N | 73 57' 45" W | 7 | 7 | 7 |
| 17 | 40 46' 16" N | 73 57' 43" W | 40 46' 16" N | 73 57' 43" W | 1 | 1 | 1 |
| 18 | 40 46' 15" N | 73 57' 42" W | 40 46' 15" N | 73 57' 42" W | 3 | 3 | 3 |
| 19 | 40 46' 17" N | 73 57' 41" W | 40 46' 16" N | 73 57' 41" W | 25 | 25 | 25 |
| 20 | 40 46' 14" N | 73 57' 45" W | 40 46' 14" N | 73 57' 44" W | 3 | 3 | 3 |
| 21 | 40 46' 15" N | 73 57' 48" W | 40 46' 15" N | 73 57' 48" W | 11 | 11 | 11 |
| 22 | 40 46' 15" N | 73 57' 49" W | 40 46' 16" N | 73 57' 48" W | 36 | 36 | |
| 23 | 40 46' 16" N | 73 57' 51" W | 40 46' 16" N | 73 57' 51" W | 1 | 1 | 1 |
| 24 | 40 46' 16" N | 73 57' 53" W | 40 46' 16" N | 73 57' 51" W | 52 | 52 | |
| 25 | 40 46' 17" N | 73 57' 54" W | 40 46' 17" N | 73 57' 54" W | 13 | 13 | 13 |
| 26 | 40 46' 18" N | 73 57' 54" W | 40 46' 18" N | 73 57' 53" W | 2 | 2 | 2 |
| 27 | 40 46' 20" N | 73 57' 53" W | 40 46' 20" N | 73 57' 52" W | 7 | 7 | 7 |
| 28 | 40 46' 18" N | 73 57' 51" W | 40 46' 18" N | 73 57' 49" W | 51 | 51 | |
| 29 | 40 46' 18" N | 73 57' 49" W | 40 46' 18" N | 73 57' 48" W | 39 | 39 | |
| 30 | 40 46' 17" N | 73 57' 48" W | 40 46' 17" N | 73 57' 48" W | 5 | 5 | 5 |

# APPENDIX C

## National Geodetic Survey (NGS) Data Sheets For New York

- **Times Square, NY**
- **Upper East Side, NY**

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1         National Geodetic Survey,   Retrieval Date = JULY 3, 2002
 KU1446
***********************************************************************
 KU1446  DESIGNATION -  817
 KU1446  PID         -  KU1446
 KU1446  STATE/COUNTY-  NY/NEW YORK
 KU1446  USGS QUAD   -  CENTRAL PARK (1979)
 KU1446
 KU1446                        *CURRENT SURVEY CONTROL
 KU1446  ___________________________________________________________________
 KU1446* NAD 83(1986)-  40 45 26.     (N)    073 59 23.     (W)    SCALED
 KU1446* NAVD 88     -        14.596  (meters)      47.89   (feet)  ADJUSTED
 KU1446  ___________________________________________________________________
 KU1446  GEOID HEIGHT-         -31.73  (meters)                     GEOID99
 KU1446  DYNAMIC HT  -          14.591 (meters)      47.87   (feet)  COMP
 KU1446  MODELED GRAV-     980,251.1   (mgal)                       NAVD 88
 KU1446
 KU1446  VERT ORDER  -  FIRST     CLASS II
 KU1446
 KU1446.The horizontal coordinates were scaled from a topographic map and
have
 KU1446.an estimated accuracy of +/- 6 seconds.
 KU1446
 KU1446.The orthometric height was determined by differential leveling
 KU1446.and adjusted by the National Geodetic Survey in June 1991.
 KU1446
 KU1446.The geoid height was determined by GEOID99.
 KU1446
 KU1446.The dynamic height is computed by dividing the NAVD 88
 KU1446.geopotential number by the normal gravity value computed on the
 KU1446.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 KU1446.degrees latitude (g = 980.6199 gals.).
 KU1446
 KU1446.The modeled gravity was interpolated from observed gravity values.
 KU1446
 KU1446;                   North         East     Units  Estimated Accuracy
 KU1446;SPC NY E     -   213,720.      193,090.      MT  (+/- 180 meters
Scaled)
 KU1446
 KU1446                         SUPERSEDED SURVEY CONTROL
 KU1446
 KU1446  NGVD 29     -        14.927  (m)          48.97   (f) ADJ UNCH    1
2
 KU1446
 KU1446.Superseded values are not recommended for survey control.
 KU1446.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 KU1446.See file dsdata.txt to determine how the superseded data were
derived.
 KU1446
 KU1446_MARKER: B = BOLT
 KU1446_SETTING: 30 = STEP
 KU1446_STAMPING: B M
 KU1446_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 KU1446
 KU1446  HISTORY     - Date     Condition        Report By
```

```
KU1446  HISTORY     - UNK      MONUMENTED       NYBE+A
KU1446  HISTORY     - 1952     GOOD             NGS
KU1446
KU1446                          STATION DESCRIPTION
KU1446
KU1446'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
KU1446'AT NEW YORK.
KU1446'AT NEW YORK, IN BOROUGH OF MANHATTAN, AT INTERSECTION OF 8TH
KU1446'AVENUE AND WEST 42ND STREET, ABOUT 17 FEET SOUTHEAST OF SOUTHEAST
KU1446'CURB OF 8TH AVENUE, ABOUT 42 FEET SOUTHWEST OF SOUTHWEST CURB
KU1446'OF WEST 42ND STREET, A 7/8-INCH COPPER BOLT SET IN THE TOP OF
KU1446'NORTHEAST END OF TOP STEP TO ENTRANCE TO FRANKLIN SAVINGS BANK,
KU1446'8 FEET NORTHEAST OF CENTER OF ENTRANCE, 2.7 FEET SOUTHWEST OF
KU1446'NORTHEAST END OF STEP, 1.6 FEET SOUTHEAST OF NORTHWEST EDGE OF
KU1446'STEP AND ABOUT 2 1/2 FEET ABOVE LEVEL OF SIDE WALK.
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1        National Geodetic Survey,   Retrieval Date = JULY  3, 2002
 KU1447
***********************************************************************
 KU1447  DESIGNATION -  818
 KU1447  PID         -  KU1447
 KU1447  STATE/COUNTY-  NY/NEW YORK
 KU1447  USGS QUAD   -  CENTRAL PARK (1979)
 KU1447
 KU1447                         *CURRENT SURVEY CONTROL
 KU1447  ___________________________________________________________________
 KU1447* NAD 83(1986)-  40 45 26.     (N)    073 59 23.     (W)     SCALED
 KU1447* NAVD 88     -        14.725  (meters)      48.31   (feet)  ADJUSTED
 KU1447  ___________________________________________________________________
 KU1447  GEOID HEIGHT-         -31.73  (meters)                     GEOID99
 KU1447  DYNAMIC HT  -          14.720 (meters)      48.29  (feet)  COMP
 KU1447  MODELED GRAV-     980,251.1   (mgal)                       NAVD 88
 KU1447
 KU1447  VERT ORDER  -  FIRST     CLASS II
 KU1447
 KU1447.The horizontal coordinates were scaled from a topographic map and
have
 KU1447.an estimated accuracy of +/- 6 seconds.
 KU1447
 KU1447.The orthometric height was determined by differential leveling
 KU1447.and adjusted by the National Geodetic Survey in June 1991.
 KU1447
 KU1447.The geoid height was determined by GEOID99.
 KU1447
 KU1447.The dynamic height is computed by dividing the NAVD 88
 KU1447.geopotential number by the normal gravity value computed on the
 KU1447.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 KU1447.degrees latitude (g = 980.6199 gals.).
 KU1447
 KU1447.The modeled gravity was interpolated from observed gravity values.
 KU1447
 KU1447;                   North         East     Units  Estimated Accuracy
 KU1447;SPC NY E     -   213,720.      193,090.      MT  (+/- 180 meters
Scaled)
 KU1447
 KU1447                          SUPERSEDED SURVEY CONTROL
 KU1447
 KU1447  NGVD 29     -        15.056  (m)          49.40   (f) ADJ UNCH    1
2
 KU1447
 KU1447.Superseded values are not recommended for survey control.
 KU1447.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 KU1447.See file dsdata.txt to determine how the superseded data were
derived.
 KU1447
 KU1447_MARKER: Z = SEE DESCRIPTION
 KU1447_SETTING: 36 = BUILDING
 KU1447_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 KU1447
 KU1447  HISTORY     - Date     Condition        Report By
 KU1447  HISTORY     - UNK      MONUMENTED       NYBE+A
 KU1447  HISTORY     - 1952     GOOD             NGS
 KU1447
```

```
KU1447                          STATION DESCRIPTION
KU1447
KU1447'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
KU1447'AT NEW YORK.
KU1447'AT NEW YORK, IN BOROUGH OF MANHATTAN, AT INTERSECTION OF 8TH
KU1447'AVENUE AND WEST 42ND STREET, ABOUT 20 FEET SOUTHEAST OF SOUTHEAST
KU1447'CURB OF 8TH AVENUE, ABOUT 20 FEET SOUTHWEST OF SOUTHWEST CURB OF
KU1447'WEST 42ND STREET, A CHISELED T IN THE VERTICAL FACE AT NORTH
KU1447'CORNER OF FRANKLIN SAVINGS BUILDING, 0.7 FOOT SOUTHWEST OF NORTH
KU1447'CORNER OF BUILDING, 13.2 FEET NORTHEAST OF NORTHEAST EDGE OF
KU1447'NORTHWEST ENTRANCE TO BUILDING AND ABOUT 2 1/2 FEET ABOVE SIDE WALK.
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1        National Geodetic Survey,   Retrieval Date = JULY  3, 2002
 KU1440
*************************************************************************
 KU1440  DESIGNATION -  L 339
 KU1440  PID         -  KU1440
 KU1440  STATE/COUNTY-  NY/NEW YORK
 KU1440  USGS QUAD   -  CENTRAL PARK (1979)
 KU1440
 KU1440                         *CURRENT SURVEY CONTROL
 KU1440  ___________________________________________________________________
 KU1440* NAD 83(1986)-  40 45 55.     (N)    073 58 26.     (W)     SCALED
 KU1440* NAVD 88     -        12.060  (meters)       39.57   (feet)  ADJUSTED
 KU1440  ___________________________________________________________________
 KU1440  GEOID HEIGHT-         -31.68  (meters)                      GEOID99
 KU1440  DYNAMIC HT  -          12.056 (meters)       39.55  (feet)  COMP
 KU1440  MODELED GRAV-     980,253.6   (mgal)                        NAVD 88
 KU1440
 KU1440  VERT ORDER  -  FIRST     CLASS II
 KU1440
 KU1440.The horizontal coordinates were scaled from a topographic map and
have
 KU1440.an estimated accuracy of +/- 6 seconds.
 KU1440
 KU1440.The orthometric height was determined by differential leveling
 KU1440.and adjusted by the National Geodetic Survey in June 1991.
 KU1440
 KU1440.The geoid height was determined by GEOID99.
 KU1440
 KU1440.The dynamic height is computed by dividing the NAVD 88
 KU1440.geopotential number by the normal gravity value computed on the
 KU1440.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 KU1440.degrees latitude (g = 980.6199 gals.).
 KU1440
 KU1440.The modeled gravity was interpolated from observed gravity values.
 KU1440
 KU1440;                   North         East     Units  Estimated Accuracy
 KU1440;SPC NY E     -   214,620.      194,420.      MT  (+/- 180 meters
Scaled)
 KU1440
 KU1440                          SUPERSEDED SURVEY CONTROL
 KU1440
 KU1440  NGVD 29     -        12.392  (m)          40.66   (f) ADJ UNCH    1
2
 KU1440
 KU1440.Superseded values are not recommended for survey control.
 KU1440.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 KU1440.See file dsdata.txt to determine how the superseded data were
derived.
 KU1440
 KU1440_MARKER: DB = BENCH MARK DISK
 KU1440_SETTING: 66 = SET IN ROCK OUTCROP
 KU1440_STAMPING: L 339 1952
 KU1440_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
 KU1440+STABILITY: POSITION/ELEVATION WELL
 KU1440
 KU1440  HISTORY     - Date     Condition        Report By
 KU1440  HISTORY     - 1952     MONUMENTED       CGS
```

```
KU1440
KU1440                          STATION DESCRIPTION
KU1440
KU1440'DESCRIBED BY COAST AND GEODETIC SURVEY 1952
KU1440'AT NEW YORK.
KU1440'AT NEW YORK, IN BOROUGH OF MANHATTAN, NEAR THE SOUTH CORNER OF
KU1440'CENTRAL PARK, ABOUT 40 YARDS NORTHEAST OF NORTHEAST CURB OF CENTRAL
KU1440'PARK SOUTH (WEST 59TH STREET), ABOUT 125 YARDS NORTHWEST OF
KU1440'NORTHWEST CURB OF 5TH AVENUE, IN THE TOP OF LOWER SOUTH PART OF A
KU1440'NATURAL OUTCROP OF ROCK, 12 FEET EAST OF NORTHEAST END OF AN
KU1440'IRON RAIL SEPARATING WALK FROM THE POND, 20 1/2 FEET NORTH-NORTHWEST
KU1440'AND ACROSS WALK FROM AN IRON LAMP POST AND ABOUT 1 1/2 FEET
KU1440'ABOVE LEVEL OF WALK.
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1        National Geodetic Survey,   Retrieval Date = JULY  3, 2002
 KU4021
***********************************************************************
 KU4021  DESIGNATION -  MANHATTAN CARLYL HOTEL APT TWR
 KU4021  PID         -  KU4021
 KU4021  STATE/COUNTY-  NY/NEW YORK
 KU4021  USGS QUAD   -  CENTRAL PARK (1979)
 KU4021
 KU4021                         *CURRENT SURVEY CONTROL
 KU4021  ___________________________________________________________________
 KU4021* NAD 83(1996)-  40 46 27.94104(N)    073 57 47.13542(W)     ADJUSTED
 KU4021* NAVD 88     -
 KU4021  ___________________________________________________________________
 KU4021  LAPLACE CORR-          5.40  (seconds)                     DEFLEC99
 KU4021  GEOID HEIGHT-        -31.64  (meters)                      GEOID99
 KU4021
 KU4021  HORZ ORDER  -  THIRD
 KU4021
 KU4021.The horizontal coordinates were established by classical geodetic
methods
 KU4021.and adjusted by the National Geodetic Survey in January 1999.
 KU4021
 KU4021
 KU4021.The Laplace correction was computed from DEFLEC99 derived
deflections.
 KU4021
 KU4021.The geoid height was determined by GEOID99.
 KU4021
 KU4021;                    North         East     Units   Scale
Converg.
 KU4021;SPC NY E     -   215,638.602   195,321.976   MT  0.99992527 +0 21
02.3
 KU4021;SPC NJ       -   215,638.602   195,321.976   MT  0.99992527 +0 21
02.3
 KU4021;SPC NY L     -    67,490.166   303,115.712   MT  0.99999577 +0 01
26.9
 KU4021;UTM  18      - 4,514,234.062   587,502.791   MT  0.99969424 +0 40
38.0
 KU4021
 KU4021                          SUPERSEDED SURVEY CONTROL
 KU4021
 KU4021  NAD 83(1996)-  40 46 27.94100(N)    073 57 47.13586(W) AD(       ) 4
 KU4021  NAD 83(1992)-  40 46 27.94012(N)    073 57 47.13646(W) AD(       ) 4
 KU4021  NAD 83(1986)-  40 46 27.94409(N)    073 57 47.13627(W) AD(       ) 4
 KU4021  NAD 27      -  40 46 27.57800(N)    073 57 48.63600(W) AD(       ) 3
 KU4021
 KU4021.Superseded values are not recommended for survey control.
 KU4021.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 KU4021.See file dsdata.txt to determine how the superseded data were
derived.
 KU4021
 KU4021_MARKER: 55 = TOWER
 KU4021
 KU4021  HISTORY     - Date     Condition        Report By
 KU4021  HISTORY     - 1932     FIRST OBSERVED   CGS
 KU4021
```

```
KU4021                          STATION DESCRIPTION
KU4021
KU4021'DESCRIBED BY COAST AND GEODETIC SURVEY 1932 (RWW)
KU4021'THE TOWER E OF THE HUDSON RIVER, IN MANHATTAN AT E 77TH STREET AND
KU4021'MADISON AVENUE ATOP THE 35-STORY BUILDING OF THE CARLYLE HOTEL AND
KU4021'APARTMENTS (A TAN-FACE-BRICK BUILDING, THE TOWER OF WHICH IS
KU4021'ROOFED WITH GOLD TILE).  A GOLD FINIAL SURMOUNTS THE STEEP SLOPING
KU4021'TILE ROOF.
KU4021'
KU4021'THE STATION IS THE CENTER OF THE FINIAL, APPROXIMATELY 400 FEET
KU4021'ABOVE THE STREET LEVEL.
```

# APPENDIX D

## Field Trial Agenda / Participants

# Voicestream GeoMode Field Trial - 23 July, 2002

**Meeting Location:** **Ireland House**
**345 Park Avenue, 17th Floor**
**New York, NY 10154-0037**
**+1 (212) 371-3600**

## *Participants:*

Digital Earth Systems –
1. Jim McGeough, CEO, DES Inc.
2. Dr. Henry Tirri, Director, GeoMode Technology
3. Tomi Silander, Project Manager

Voicestream Wireless –
1. Ryan Jensen, Principal Engineer
2. Jim Nixon – Regulatory Affairs

## Observers:
1. PlanGraphics, Inc., – Richard Goodden, VP
2. American Red Cross – Luis Avila, Disaster Capital Initiative Program Manager

## *Proposed Agenda:*

09.00 – Welcome

09.15 – GeoMode Introduction – General description of the wireless environment and location positioning technology

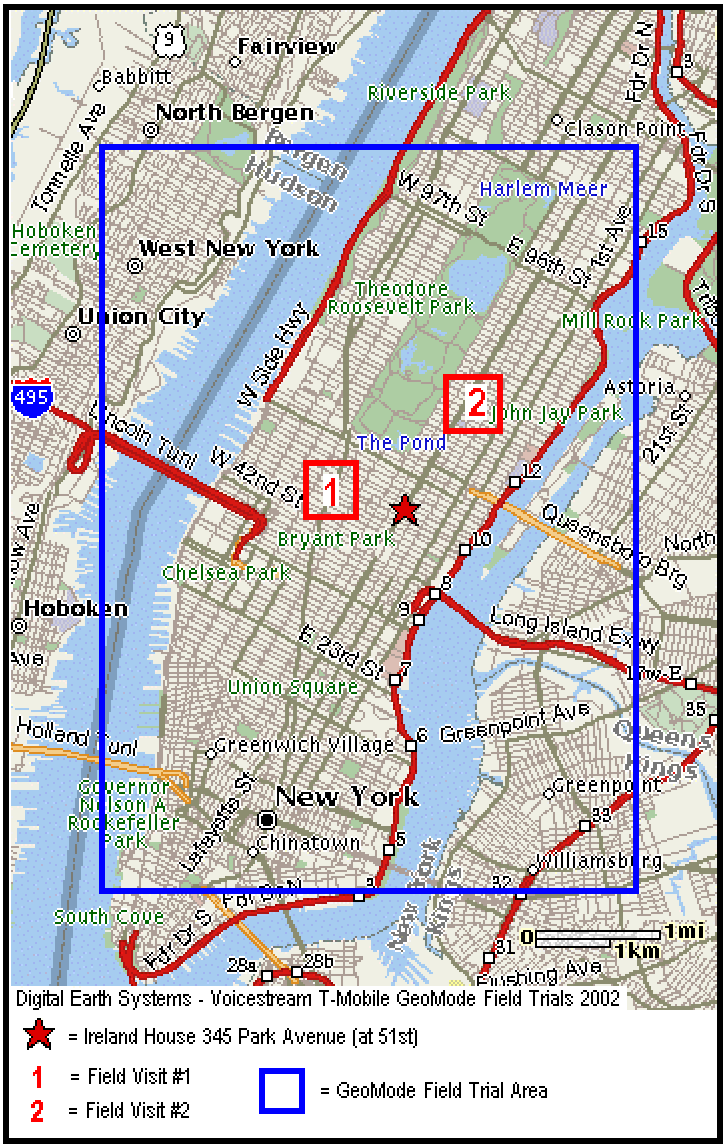
10.00 – Technology Discussion – System architecture, scalability and GeoMode software algorithm methodology including operation issues such as Rf model building and maintenance.

11.00 – Depart for Times Square
11.30 – Field Visit Session #1 – Application accuracy validation and comparison to GPS and NY City Survey Marks
12.30 – Depart for E72nd Street
13.00 – Field Visit Session #2 - – Application accuracy validation and comparison to GPS and NY City Survey Marks
14.00 – Conclude Field Session
14.30 – Analysis, Report, & Conclusion

NOTE 1: A description of the Field Trial demonstration scenarios will be provided for discussion prior to the field visits. The scenarios will be designed to simulate the accuracy requirements necessary for the FCC E-911 mandate and other LBS applications.

# GeoMode Manhattan Field Trial

## Location Map




**Some Recommended Hotels in the Area:**

1. Algonquin Hotel, 59 W44 Street – (212) 840-6800
2. Essex House Hotel, 160 Central Park South - (212) 247-0300
3. Warwick Hotel, 65 W 54th St - (212) 247-2700
4. Phillips Club, 155 W 66th St – (212) 835-8800
5. Bradford, 210 W 70th St Lbby – (212) 787-5700
6. Hotel Spencer Arms, 140 W 69th St – ((212) 787-4700
7. Inn New York City, 266 W 71st St – (212) 580-1900

# APPENDIX E

## GeoMode A-NSS / A-HSS Implementation Guidelines

**GeoMode A-NSS / A-HSS Implementation Guidelines**

## Implementation Guidelines

GeoMode is a server based 100% software solution that uses only existing signal data to compute the location of a mobile station (MS). In wireless cellular networks, the signal data between any Base Station (BST) and all activated handsets is measured / polled by the network at sub-second intervals to facilitate handover between cells. This signal propagation data for all mobiles (MS) is managed in the network by base station controllers (BSC); GeoMode may be installed in the network (A-NSS) where it has access to this data via the 'Lb' interface. Or GeoMode may be installed outside the network (A-HSS), on a web server. For the A-HSS option, the subscriber requires a 'smart' phone and the signal data is captured on the mobile directly using a small applet (Java, WAP, Brew or WinCE) provisioned to the MS by the GeoMode application server. Therefore, GeoMode can be network based or handset based.

The location of the GeoMode server can vary depending on the network provider and operator preferences. The implementation options and interfaces are identified in the diagram below:

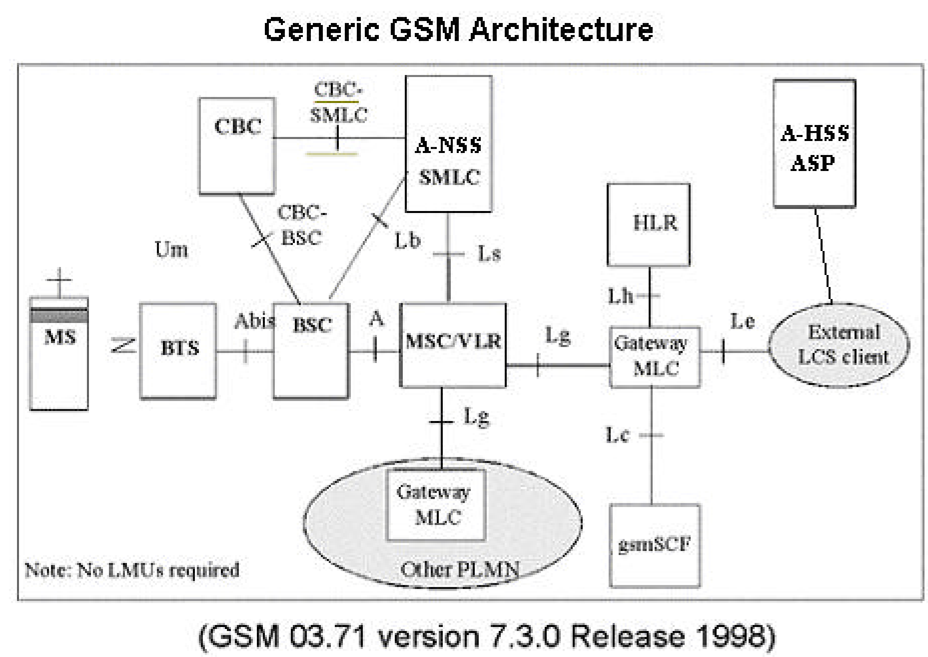



Figure 1: Generic GSM Architecture showing the A-NSS and A-HSS options for network based or handset based implementation

**GeoMode A-NSS - Network based Option**

The following Network based / Hybrid Model (Any legacy device) scenario applies to wireless carriers that wish to implement and manage A-NSS from within the network. This option allows the wireless carrier to locate all mobile devices including legacy handsets:

- A-NSS on a Serving Mobile Location Center (SMLC) receives the signal data for all subscriber handsets (MS) from the Base Station Controller (BSC) via the "Lb" interface
- A-NSS processes the X,Y location for subscribers on request
- The specific phone location data (X,Y) is made available to LBS Platform / Middleware on request or passed direct to a 3rd party commercial LBS application via the network external Gateway MLC / IP connection
- The X,Y data can be routed to any carrier application or external E911 PASP

**GeoMode A-HSS - Handset based Option**

The following Handset based scenario applies to wireless carriers, enterprise customers or ASPs that wish to implement A-NSS independently of the network. This option computes the location of subscribers with smart phones or PDAs such as WAP 1.2, JAVA, Brew or WinCE devices;

- The subscriber uses data services to connect to a promoted LBS application web server
- Upon connection, web server provisions an applet (one-time download) to the device
- The applet on the handset / device (MS) is continuously collecting signal data (down-link) specified above directly from the base stations (BTS) and store 20 seconds of data.
- This data is sent by the applet to the LBS application server over data services.
- The LBS server / A-NSS Server processes the location for each specific phone
- The specific phone location data (X,Y) is provided to the requesting application.
- The X,Y data can also be routed to any carrier application or E911 PSAP.

End of document